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Substantiation of parameters of underground geotechnology in the development of complex structural deposit of various grades of ores

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Abstract. Analysis of mining production activities at the current stage of field development shows an acute deficit in mineral raw materials. At present, most enterprises have exhausted all their prospective reserves and inevitably return to the reserve. Such sites have as a rule a low content of the useful component, are composed of different-grade ores and are located in difficult mining and geological and technical conditions.Their development requires significant capital investment and accordingly this leads to a decrease in the profitability of production. In order to maintain production capacity and extend the life of the field, companies are forced to ensure their development, despite a decrease in overall profits.The search for possible technologies for mining these areas of deposits is an urgent and priority direction for many enterprises. So, in the presented report are the optimal variants of the development of deposits shown, it is represented by different-grade ore bodies, most of them are stacked off-balance ores. The presented solutions make it possible to increase the life of the enterprise by increasing the reserves of previously substandard ores.

1. Introduction

After working off the main reserves of copper pyrite deposits, as a rule, there are reserves dispersed throughout the mine field in the form of separate lenticular low-power ore bodies with complex morphology and low content of the useful component. The company is forced to work out such areas, both under the condition of compliance with the requirements for full recovery of reserves, and to maintain production capacity and extend the life of the field [1–5].

In modern mining, we have accumulated vast experience in working out low-power and dispersed ore bodies that represent the main reserves of the Deposit. The question of working off of newly discovered, left ‘or later’ complex ore bodies stays unaffected and highly relevant at the present time.

The solution of this question is made on the example of the development of the I-th Deposit of the Kamagansky field (Republic of Bashkortostan), represented by a group of lenticular ore bodies with a capacity from 1–1.5 m to 20 m and an angle of incidence from 0 to 30° [6,7]. In total, 15 ore bodies were identified, lying in tiers in the range of 47.4 to 726.5 m, the dimensions along the stretch from 50 to 320 m, in the cross – from 20 to 160 m. Ores (both balance and off-balance) are mostly thickly interspersed, in the form of debris, rarely there are separate intervals of solid ores with a content of copper from 0.68 to 2.9 % and zinc from 1.0 to 2.3 %. Ore bodies have interlayers of waste rocks.

The operational reserves of the Deposit (up to the border of the mining lease) are 703.45 thousand tons.

At present, the ores of the I-th Deposit are the necessary raw material base for replenishing the outgoing capacity of the Kamagansky field and maintaining the stable operation of the enterprise for the coming years. Therefore, realization of research on the feasibility study of underground geotechnologies for the development of the I-th Deposit is a very relevant issue at this stage of the development of the enterprise.

Due to the scatter of ore bodies along the mining lease, the development of the Deposit requires significant capital investment and as a result, will lead to unprofitable operation of the mine. However, write-off of these reserves is not possible due to the relatively large volumes of reserves and the amount of metal. The conducted research has shown the need for joint development of the I-th Deposit and the main reserves of the field. At the same time, there is an increase in profit due to the prolongation of term of development of the field.

2. Research methods

The paper uses a comprehensive research method, that includes along with design solutions, analysis and generalization of the practice of developing dispersed long-lying ore bodies, analytical research, methods of mathematical statistics and technical and economic analysis, as well as economic and mathematical modeling.

3. The main part

An acute shortage of raw materials for production of mining operations forces enterprises to solve issues related to the development of areas of the field that were once left in the subsurface, due to the complexity of their occurrence, or low profitability of development. Currently, this issue is relevant and requires a comprehensive scientific and technical justification of options and parameters of geotechnical development of such sites.

So, because of depletion of operational reserves by the development of the Oktyabrsky field sites (ore bodies) scattered across the mine field are putting into commercial operation. As an example, we can give design solutions for the development of reserves in the Tashkulinsky area [8,9]. Technical and economic modeling of options for opening and working out this section predetermined the maximum use of existing mining and capital workings. At the same time, the option of geotechnology with the lowest possible time for commissioning of the site and the procedure for mining ore bodies was determined. First of all, ore bodies 31 and 34, located between the horizons of 220–300 m, are worked out. Ore bodies located above the horizon of 220m are worked out in a retreating order-28, 29, 33, 30 and 27.

Thus, the use of existing workings of the Oktyabrsky underground mine by opening up the reserves of the Tashkulinsky area allowed to reduce the volume of mining and capital works.

Design solutions for refining the ore bodies of the Kamagansky Deposit also prove the feasibility of putting previously unprofitable sections into operation [10].The design took into account the main requirement for the development of this type of field, which is a quick return on investment, and therefore a minimum time to achieve the design capacity and intensity of development of the field.

A striking example of commissioning an unprofitable section of the field is the design solution for underground geotechnology for the development of ‘non-core’ sections of the I-th Deposit of the Kamagansky field, represented by dispersed low-power ore bodies.

The Kamagansky field is a classic implementation of sequential combined geotechnology. All underground reserves are opened from the quarry by three tunnels located on different horizons. Reserves subject to underground development are located in the North-Western (section of ore bodies (O.B) 3 and 5) and North-Eastern (O.B 12) sides of the quarry. At present O.B. 12 has been fully worked out and O.B. 3 and 5 are being finalized.

After detailed operational exploration the contours of the O.B. 12 were clarified, whose callout was not developed by open pit mining in the southern part of the field.

The I-th Deposit under consideration is located a little to the West of O.B 12. A peculiarity of the site is the longline occurrence of numerous low-power ore bodies with the content of a useful component, that varies in a wide range. Development of the site is complicated by the large indentation of the array by tectonic disturbances and numerous cracks of the ordinary order, as well as the close location of the upper ore body to the surface (less than 50 m).Moreover, in the zone of influence of underground mining operations is an oil depot, which belongs to the second category of protection.

Geomechanical calculations and mathematical modeling have shown that the predicted values of surface deformations do not exceed the permissible values for this category of protected objects, so there is no need to move oil base buildings beyond the displacement zone [11].

For the purpose of effective implementation of underground geotechnology was zoning of ore bodies of the I-th Deposit according to the elements of occurrence and the content of the useful component conducted and intervals of application of underground mining systems were established.

The presence of protected objects has predetermined the use of development systems with a full laying of the developed space or leaving the regular ore and the artificial pillars by the low power of the ore bodies.

The final choice of development systems was made by economic and mathematical modeling of options for each ore body, based on the criteria of maximum profit and minimum cost [12,13].

Based on the empirical dependencies on the comparative evaluation of mining systems given in V V Grigoriev's dissertation [14], relevant indicators were calculated for various variants of mining systems and a rational variant was selected for each ore body:

- camera development system with a laying (ore bodies with a capacity of more than 10–12 m at any angle of incidence);
- room-and-pillar development with a single-layer excavation and laying at the power of the ore body 2–6 m and 6–10 m (ore bodies and clippings with a capacity of 2 to 6 m with a drop angle of up to 30°);
- room-and-pillar development with leaving of the ore and the artificial support pillars (ore bodies with off-balance and substandard reserves);
- room-and-pillar development with delivery of ore by force of explosion (sections of ore bodies with an angle of incidence greater than 30–35°).

Variants of the quarrying schemes were subjected to technical and economic modeling:

- two existing tunnels of the horizon: 140 m and 90 m;
- tunnels of the horizon 140 m and elevator rising
- two vertical barrels from the surface;
- tunnels of the horizon: 140 m and crosscut ‘Novy Sibay–Kamagan’.

Calculations have shown that in order to reduce the capital costs of dispersed ore bodies of long-range occurrence, an opening scheme is necessary with maximum use of existing capital workings, as well as conditional division of the Deposit into sections and their phased commissioning with separate airing of each as mining operations develop. Thus, the I-th Deposit of the Kamagansk field should be divided into three independent sections by depth:

- reserves located in the floor of 140–50 m (from the surface to the bottom of the quarry);
- reserves-140–330 m (from the bottom of the quarry to the borders of the mountain branch);
- reserves located below the mountain branch.

The first complex (starting). As the main opening development is tunnel on the horizon 140 m used, it serves for fresh air supply, rock mass issuance, people's entrance and exit and delivery of materials. From the tunnel behind the zone of displacement on the lower section (140–330 m)for cleaning operations passes an inclined slope on horizon 50/140 m, that connect the operational horizons of the site. The Elevator rising horizon of 0/120 m serves for the release of polluted air and as a second mechanized exit. The method of airing is injection, using the existing fan installation at the portal of the horizon 140 m ad it, which includes a VZP-16 fan. Fresh air is fed through the tunnel to the inclined exit, washes the areas of treatment works and through the Elevator rising 0/120 m is issued to the surface.

Second complex. After commissioning of the first starting complex, it is planned to build an underground mine below the bottom of the quarry to the mountain branch (330 m).It is planned to use the stand bore of the ‘NovySibay’ section of the Sibay Deposit as an air supply. For this is the existent crosscut ‘NovySibay – Kamagan’ used. From the existent crosscut passes inclined crosscut 210/330 m to the site of the I-th deposit.

The sections of the treatment works are connected to each other by an inclined exit horizon 140/330 m. As an emergency exit, it is planned to pass the Elevator rising horizon 140/330 m. The airing method is pressure-type. Fresh air is supplied through the stand bore of the 'NovySibay' section along an inclined crosscut at horizon of 330 m. Then it is fed to the operating areas of the ore bodies along an inclined entrance, washes the treatment works and is issued through the 140 m horizon adit in the quarry.

The third complex (final). The opening of ore bodies (No 26 and 27) located below the mining branch is carried out by deepening the inclined exit and Elevator rising. The opening of the I-th Deposit of the Kamagansky Deposit is shown in Figure1.

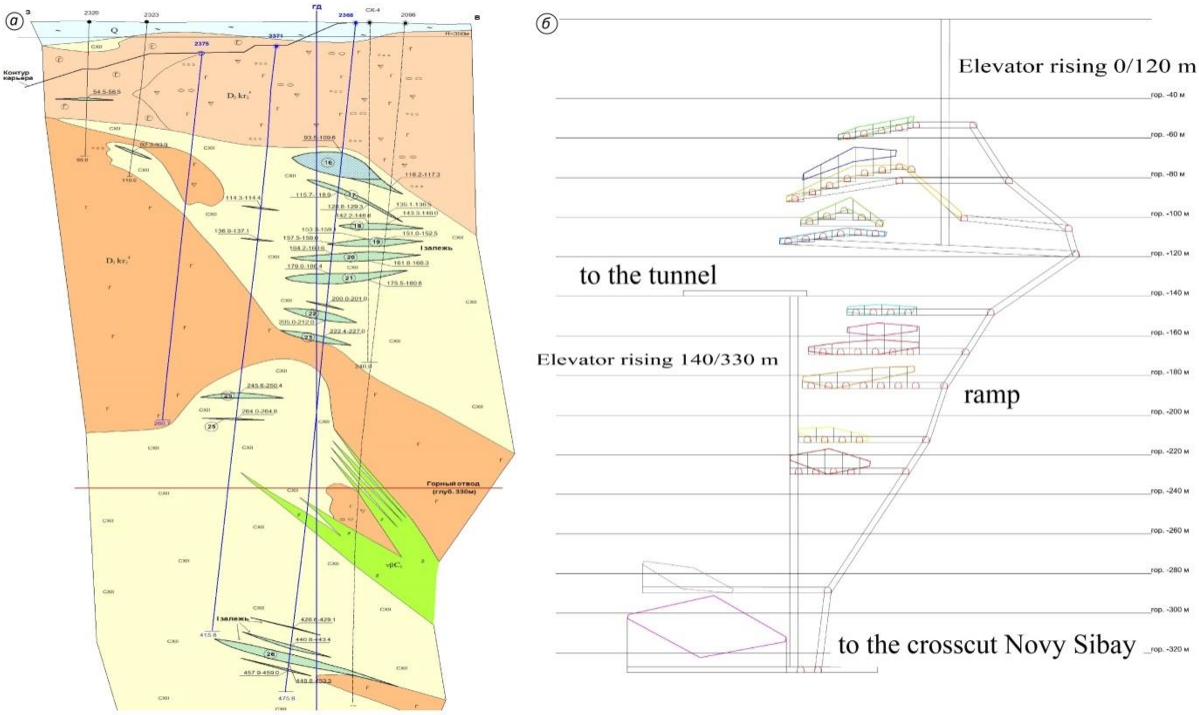

Figure 1. Geological section (a) and opening scheme of the I-th Deposit (b).

Due to the small capacity of the ore bodies was ore preparation from delivery drifts from an inclined slope accepted, that was passed in a supine side outside the zone of influence of the East Sibai tectonic fracture. An inclined slope is passed as close as possible to the dredging area in order to reduce the length of the field delivery drift [15]. Every ore body is a dredging site and the height of the floor (sub-floor) can vary depending on the morphology and conditions of occurrence, but not more than 40 m.

Preparatory work is to carry out on each excavation site mining complexes, which are necessary for production of ore reserves by the accepted development systems.

In General, the preparation of ore bodies of the Deposit is the same and consists in carrying out delivery and ventilation-laying drifts on the flanks of the ore body and brought together by drilling and delivery orts. The location of the ventilation and stowage drift is selected taking into account the difference in marks between the delivery drift. Orts are drawn along the axis of the worked out camera. Ore bodies with relatively small layers of empty rocks between them are worked out in one section. At the same time, several mining sites may be in development. The development of reserves in the lower-lying area can be started after the front of the treatment excavation in the upper section is shifted beyond the displacement zone, built at the appropriate angles, but not less than 20 m relative to the upper border of the ore body in the lower section.

The final detailed technical and economic calculation of the accepted variant of underground geotechnologies of dispersed ore bodies of long-range occurrence, which is the most optimal, showed the inefficiency of mining the reserves of the I-th ore Deposit of the Kamagansky field (at the dressing stage). In this regard, a variant of simultaneous mining of the I-th Deposit and the reserves of the lens out of O.B. 12 was analyzed. Technical and economic modeling indicators are shown in Figure 2 (profit indicators are taken as conventional units for the purpose of non-disclosure of trade secrets and are provided as a comparative analysis).

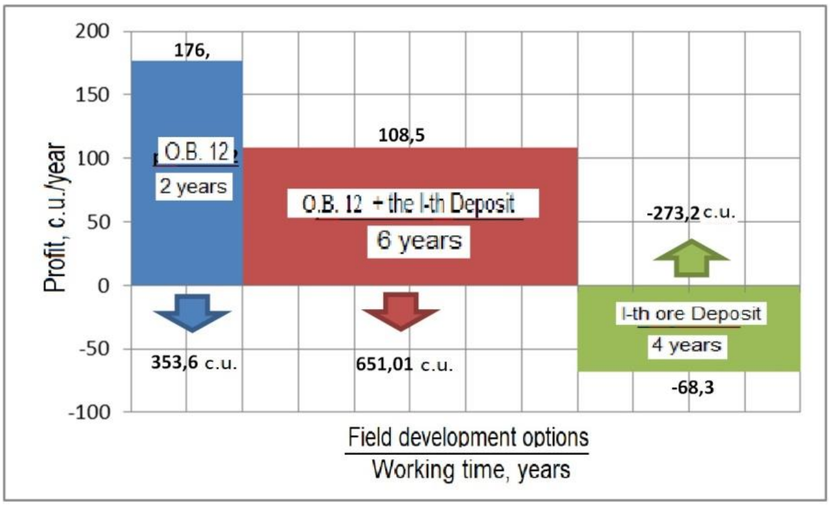

Figure 2. Indicators of technical–economic modeling.

Based on the technical and economic modeling the loss from the development of the I-th Deposit will be 273.2 conventional units. The feasibility of joint mining of the I-th Deposit and the undeveloped quarry of the southern clipping of O.B. 12 is clear. The annual profit will be 108.5 cu for a six-year period of development. Total profit is more than 651 conventional units. Individual development of the O.B. 12 increases the annual profit of the enterprise (up to 176.8 cu), but the term of development is reduced to 2 years.

Thus, the development of an unpromising site of low-power dispersed ore bodies is possible under the condition of maximum use of existing mining and capital workings. At the same time, it is necessary to divide the Deposit into operational sections with individual opening and airing method, and gradually introduce the sections of the Deposit into development. In case of tiered occurrence of dispersed ore bodies, in connection with the opening of the Deposit to the full depth, all ore bodies, both balance and off-balance, are subject to excavation. This solution allows to increase the volume of commercial ore of the site at a constant level of capital investment. It is possible to increase the profitability of the site by parallel treatment excavation of the main reserves of the field.

4. Conclusion

The paper contains a solution to an actual scientific and practical problem, which consists in the development and scientific justification of the parameters of the technology for working out a complex-structure Deposit, represented by a group of closely spaced ore bodies of long-range occurrence, which is important for the science and practice of the mining industry.

Main scientific results, practical conclusions and recommendations:

1. It is established that in the case of long-line occurrence of close ore bodies, the Deposit is worked out without combining them into a single ore zone, and it is advisable to work out all the ore bodies regardless of the quality of the ore. Opening of the Deposit is made taking into account the maximum use of existing mining and capital workings and preferred ore preparation.

2. By selecting of development systems is preliminarily zoning of the ore bodies by occurrence elements and content of a useful component produced. Zoning is performed to pre-select a particular version of the development system. The final choice of technology is made by economic and mathematical modeling of the mining of each ore body according to the indicators of maximum profit and minimum cost.

3. A rational order for the development of the mining front has been defined in order to minimize initial capital investment, which consists in dividing the Deposit vertically into sections with separate airing and putting them into operation in turn.

4. The technical and economic assessment showed that the development of deposits with a similar

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structure and morphology is appropriate for maintaining the production capacity of the enterprise only in conjunction with the development of more promising areas of the field. Individual mining of the Deposit is preferable at higher prices for raw materials and the dollar exchange rate.

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